WooGu: Exploring an Embodied Tangible User Interface for Supporting Children to Learn Farm-to-Table Food Knowledge

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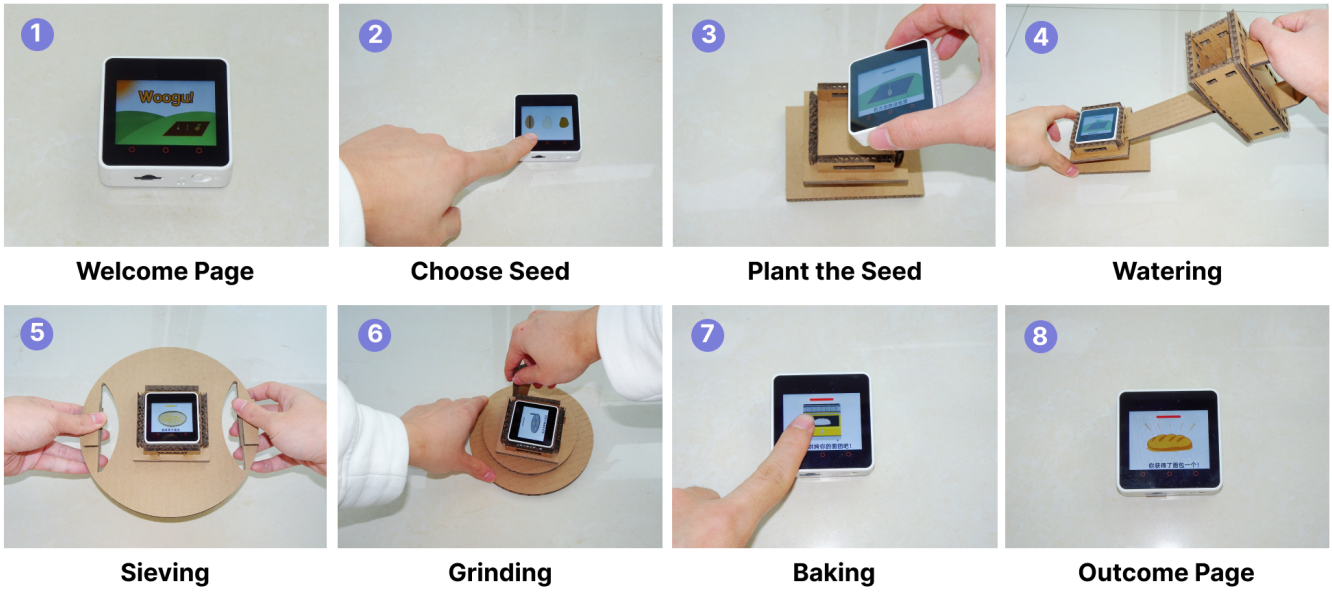

Figure 1: The user journey of WooGu

ABSTRACT

Food is essential for human health, growth, and development. However, children need more learning materials and motivation to receive food literacy education or know the fundamental food processes from farm to table. In this work, we explored the design of a prototype named WooGu with tangible user interfaces (TUI) and embodied interactions, which aims to improve young children's food literacy. WooGu presents three design features: a cube displaying user interfaces, step-by-step tasks guiding children to learn food from farm to table, and hands-on props made by cardboard empowering embodied interactions. We evaluated WooGu with two families in a pilot test, and the findings suggested that WooGu provides children with the embodied experience of food production, improving their food literacy, logical thinking, and practical ability. This research contributed to the human-food interaction area and provided a novel way of learning food literacy for children through embodied interactions with WooGu.

CCS CONCEPTS

• **Human-centered computing** → **Systems and tools for interaction design**; *User interface toolkits.*

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KEYWORDS

Embodied interaction, tangible user interface, prototype design, food literacy education

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1 INTRODUCTION

Food is essential for human health, growth, and development [17]. Knowing the food processes from farm to table can encourage children to make more informed food choices and appreciate the effort in food production, which also facilitates children's connection with the natural world [12]. However, traditional food literacy education for children primarily focuses on nutrition and lacks an explicit curriculum, suitable materials, or training to support children in learning where food comes from and how it is produced and processed [15]. Thus, researchers were concerned that food education might be superficially imparting information to children [7], which strongly highlights the necessity to explore innovative strategies for children to gain a better understanding of food literacy, including various stages in the journey of food from farm to table.

Prior work [9, 10, 13, 23] revealed that tangible user interfaces (TUI) effectively facilitated children's learning outcomes by scaffolding learning activities, promoting learning behavior, and improving engagement with multi-sensory cues in various scenarios. Specifically, researchers from Human-Food Interaction (HFI) [3] field integrate embodied interactions in TUIs to promote social eating and learning through playful experiences [20]. However, few studies have investigated that how TUIs can promote children's learning of food processes from farm to table. Therefore, we developed WooGu including an exploratory design process and a pilot user study. We aim to answer the following research questions (RQs): (1) How does the WooGu, a TUI prototype including embodied interactions, enhance children's learning about food processing from farm to table? (2) To what extent does the WooGu stimulate positive learning outcomes for children and satisfaction among parents?

We recruited two families and conducted a pilot user study, and we also interviewed two parents and three children about their usability experiences and feedback. Findings suggested that parents believed WooGu was helpful in acquiring food literacy, and children showed intense interest in hands-on embodied interactions with the cardboard props. In summary, our work contributes to the HFI area by exploring the structure and embodied interactions of a TUI educational prototype, WooGu. Our design research also offers design implications in developing future TUIs and HFI research for children's food literacy education.

2 RELATED WORK

2.1 Tangible User Interfaces in Children's Education

A previous study [10] suggested that tangible user interfaces (TUIs) improved students' task performances and learning outcomes because tangibility offers multi-sensory cues and promotes a more robust and long-lasting involvement [16]. For example, Fan et al. designed a TUI prototype to improve children's (aged 5-7) reading and writing abilities of Chinese characters through tangible cards with tactile and kinesthetic sensory feedback cues [5]. Furthermore, TUI prototypes have also been explored and applied in food literacy education. For instance, Baurley et al. investigated the embodied interactions of capturing various expressions of recipe authoring [2]. They suggested that embodied interactions informed users with adequate dimensions, feel, and movement, thus achieving a desired and memorable dish for users [2].

2.2 Food Literacy and Human-Food Interaction

Food literacy and education research cover nutritional science and a much broader ground, such as cooking, farming, gardening, agriculture, policy, exercise, and mannerisms [7, 19]. In current HFI and HCI domains, a great number of works focused on the cooking process [2, 11, 14]. For example, RecipeRadio [2] was a TUI that introduced the recipe-authoring tools for open innovations in food. It places an emphasis on children's physical engagement with cooking tools, creating a space for them to freely experiment with a variety of culinary methods. So it not only provides children with opportunities to unleash their creativity in a simulated kitchen environment, but also holds immense potential for enhancing children's culinary proficiency. However, RecipeRadio did not contain information about the origins of food. Besides, recent HCI researchers also explored opportunities in creating playful, social, and interactive eating food experiences [4, 20–22]. However, prior work mostly investigated the temporal eating experiences instead of constructing a food process from farm to table. Therefore, in this work, we designed a TUI prototype, WooGu, integrating farm-to-table food knowledge, step-by-step tasks, and hands-on props to create interactive, embodied, and playful learning experiences.

3 SYSTEM DESIGN AND IMPLEMENTATION

We aim to help children explore and learn farm-to-table food knowledge through a TUI and embodied interactions. We practiced the following design principles in the exploratory prototyping stage:

- **Provide multi-sensory feedback through the TUI.** According to prior researchers, TUI can benefit children's emotional development [18], learning activities [5], and social skills [6, 8] by providing robust and long-lasting involvement due to multi-sensory coordination. Thus, we utilized an intelligent cube that integrated visual, audio, and tactile narratives to provide children with a multi-sensory experience.
- **Deliver the knowledge through embodied interactions.** Embodied learning is most effective for children to translate knowledge into action and validate their food learning [2]. Therefore, our user journey prioritizes physical interaction

between children and cardboard props, creating a playful and engaging experience that utilizes tangible tools to educate knowledge about food from farm to table.

3.1 WooGu's Features

The name of WooGu was named after the Chinese words for "five grains" (五谷) [1], referring to five traditional grains, *i.e.*, rice, broom corn millet, grain, wheat, and bean, as well as being a general term for food. The name of WooGu implies the importance and necessity for children to learn the process of how food is planted from seeds, grown into fruits, and finally produced and offered on the table.

3.1.1 The Farm-to-Table Food Knowledge-Guiding Process and Tasks. Given that children are often removed from the contexts of food farming and production, they will find difficulties in recognizing food forms from farm to table. Diet is intertwined with behavior, morality, and personality. Positive food culture can shape children's character and behavior, and vice versa. Therefore, we implemented the essential steps in WooGu that represents the food production steps in three steps: seeds-planting and cultivating, processing, and cooking (see Figure 2). Children will first plant seeds and cultivate the seeds, (steps 2-4 in Figure 2) and then, they will process the fruits using tools (*i.e.*, cardboard props) and learn the changes of food (steps 5-6 in Figure 2). Finally, children will follow the recipes to understand culinary steps (steps 7-8 in Figure 2). Since we were at the pilot stage of exploration, we implemented the three most commonly-eaten starch food: rice, wheat, and potatoes, and provided cooking recipes for rice, bread, and french fries, accordingly.

3.1.2 The Multi-sensory Feedback from the WooGu Cube. The second core design feature of WooGu is the cube with user interfaces that provide visual, audio, and tactile multi-sensory feedback (see Figure 1). These visuals show the growing, processing, and cooking stages of wheat, rice, and potato, helping children understand and recognize food appearances and their growth and process conditions. The audio information contains instructions and supports children to better understand the interactions and user tasks. Moreover, WooGu vibrates when children complete their tasks in each stage to provide them with a sense of accomplishment.

3.1.3 Cardboard Props for Hands-on Experiences. WooGu's third design feature is the hands-on cardboard props, which enable children to simulate the embodied farming, processing, and cooking behaviors and actions happened during the three stages. In our exploratory process, we experimented and designed three hands-on props using cardboard material, including a watering can, a siever, and a stone mill (steps 4, 5, and 6 in Figure 1). Children can place the cube in the holder and use the watering can prop to water the "plant" (in the cube). The siever prop has two handle-shaped holes on both sides of the plate that children can hold and shake the "wheat" in the cube. With the round-shaped stone mill prop, children can hold the handler and grind the "wheat" into "flour" in the cube.

3.2 The Technical Solution

The cube is M5Stack Core2[1], which contains a small screen display, a speaker, and several interactive sensors. We collected data from the gyroscope sensor to detect the current movement directions and acceleration and predict children's physical interactions with the hands-on props. Also, by setting different vibrating duration times with the vibration sensor, we help children differentiate other interaction conditions such as in-process or task-done. All codes were written in Python on the UIFlow[2] editor.

4 METHOD

4.1 Participats

We recruited three children (2 males and 1 female, aged 6 to 8, with an average age of 7) and their parents (3 females, ranging from 35 to 74, with an average age of 48.34) in convenience. All three children have learned food-related knowledge before through various means, such as learning from educational toys or games, verbal teaching, and documentation. Participants voluntarily self-selected to complete the survey and consented before the study. We recruited potential participants by sending recruitment posters to school teachers and parents in the community. Our university's IRB approves the study procedure.

4.2 Measurement

We collected data from four sources: a questionnaire for demographic information, pre/post-study knowledge test for evaluating learning outcomes, observation and recorded videos for analyzing users' behavior, and the semi-structured interview to understand user experience better.

4.2.1 Food-related Knowledge Test. We administered pre- and post-food literacy evaluation tasks, including three tasks: (1) the food image transferability test, (2) the food recognition test, and (3) the process of food from farm to table test. Task 3 was designed to investigate children's mastery of food knowledge from farm to table. Following interaction with WooGu, a post-study test was administered with similar testing topics. Results were compared to investigate learning outcomes, with all test materials in Appendix A.2.

4.2.2 Researchers' Observations. To understand how children perceive the features of the WooGu and encourage them to explore the usage of the hands-on props, we displayed the cube and props on a table. We observed how children interacted with them without our introduction. Afterward, we encouraged children to think aloud and observed their facial expressions, body movement, and hand gestures while playing with WooGu. Researchers took notes and recorded the entire session with their parent's permission.

4.2.3 Semi-structured Interviews with Parents and Children. To further understand children's learning outcomes and their parent's opinions. We asked children some questions on the following topics during the semi-structured interview: (1) Food Knowledge; (2) User Experience; (3) Their suggestions and recommendations. After that, we interviewed their parents on the same topics. We listed the

[1]M5Stack Core2: https://m5stack.com
[2]UIFlow: https://m5stack.com/uiflow

complete interview scripts in the appendix. Two researchers coded the interview scripts separately using a thematic analysis method.

5 RESULTS

Here, we report children's and parents' usability and feasibility experiences of WooGu and children's learning outcomes. We also share design implications summarized from the study results.

5.1 Children's Learning Outcomes of Farm-to-Table Food-Related Knowledge

During the pre-test(*i.e.*, the food-related knowledge test), specifically the seed recognition and matching test, all three children exhibited an 80 percent accuracy rate, suggesting that they could recognize seed morphology and categories. However, in the third section of the test which assessed the children's capacity to explain the process of making rice, potato, and bread, all three children achieved only a 20 percent accuracy rate. Interestingly, after following the implementation of WooGu, the children demonstrated a significant improvement in their food-related knowledge that they become capable of providing accurate responses to questions about food knowledge, spanning from farm to table. One of the children told us in the post-interview,

> *"Now I know where bread comes from. It is wheat first and then process it to be flour via siever and stone mill. Finally, we make it into the dough and bake it in the oven to cook bread."* (P-C1).

In addition, our observations revealed that the children exhibited a keen interest and curiosity in exploring the various props in WooGu and discovering their functions in the context of food planting and processing. Notably, the children enjoyed the hands-on embodied interactions with the cardboard props, and successfully identified how to use the watering can without explicit instructions. However, the children appeared to be less familiar with other farming tools, such as the siever prop and the stone mill prop. One parent reported that she had previously taken her child to a farm and demonstrated the use of these tools, but her child still did not retain this information. However, after their interaction with WooGu, she noted that her child could explain both the apperance and using method of different props. Furthermore, all three children were motivated to explore and utilize the various farming props with WooGu and displayed enthusiasm upon completing the assigned tasks. For instance,

> *"I have watched short videos about sievers and stone mills on TikTok before, but I never used them in my life. Nevertheless, now I know how to use them, and producing food is truly complicated."* (P-C2)

His parent (P-P1) also commented that WooGu taught children the series of steps from wheat to bread, and now her child started to think more about other food's farming, processing, and production stages.

5.2 Parents' and Children's attitudes towards playing with WooGu

In the post-interview, all three parents expressed that they liked the idea of using TUI to motivate their children to learn farm-to-table food knowledge. For instance, one parent reported,

> *"I think educating [children] the process of food from farm to table is very essential to my child because it can broaden his range of knowledge and understand why we eat."* (P-P2)

Moreover, the participants expressed positive feedback regarding the embodied interactions with the cardboard props, emphasizing that such hands-on practice enabled a more realistic simulation of the farming and cooking experiences. They noted that their children primarily acquired knowledge from online videos or schools through visual and textual formats, which may not fully capture the tactile and sensory elements of the processes involved. As such, the opportunity to engage with the cardboard props in a physical manner was perceived as particularly valuable by the participants. P-P1 mentioned,

> *"My child lacks hands-on experiences and abilities. Especially due to the epidemic's impact, children study online at home and are easily disturbed by electronic devices, lacking concentration and having less opportunity to exercise their practical ability. But when he played WooGu just now, I think he behaved proactively during interactions, and he was thinking about how to tackle the challenges."*

6 CONCLUSION AND FUTURE WORK

We propose WooGu, an interactive system comprising a small screen and a set of hands-on tools to support children's learning about food production from farm to table. Our approach offers three key advantages over conventional screen-based interactive games and food toys. First, we combine the portability of small screens with the tactile experience of tangible tools to provide children with easy access to embodied knowledge about food production. Second, by integrating visual narratives with physical interactions, we help children foster an embodied understanding of the entire process of food production. Moreover, we incorporate voiceover instructions and graphic illustrations to provide multimedia feedback, enriching children's interactive experiences as well as arousing children's curiosity. And we find that using lively cartoons of food image and voice prompts helps children connect more emotionally with food, thereby fostering empathy and responsibility towards food. Finally, we break down the complex steps of food production into a continuous sequence of interactive experiences that enables children to logically acquire knowledge of food production and develop associative thinking around it.

In the future, we aim to validate the practicality and applicability of WooGu in food education and refine its design. Specifically, we plan to gamify the interactive experience of WooGu by exploring the production characteristics of different foods in-depth and transforming them into interactive game challenges. Concurrently, we intend to develop more high-fidelity hands-on tools that cater to the diversity of food production learning and ensure the sustainability

of tool usage. Finally, we seek to conduct further user research and testing to evaluate the advantages and disadvantages of WooGu for different age groups and application scenarios.

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SELECTION AND PARTICIPATION OF CHILDREN

The selection of the school was predicated upon an opportunistic occurrence of personal contact with the first author. Verbal assent was obtained from the children, while written consent was procured from their respective guardians. Only those who provided consent were included in the study.

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A APPENDICES

A.1 Food production process

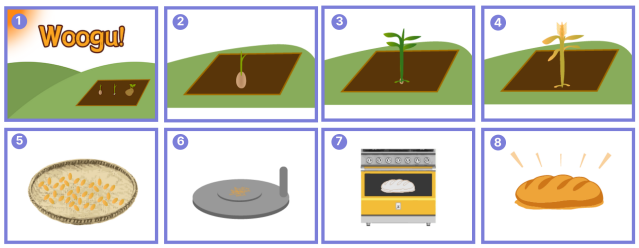

Figure 2: (1) Homepage. (2-3) Wheat grows. (4) Wheat ripens. (5) Harvest Wheat and put it into the siever. (6) Grind wheat into the flour. (7) Put the dough into the oven. (6) Bake the bread.

A.2 Pre/Post Study Test Materials

Figure 3: The cards used in Task 1. There are 12 cards in total, showcasing the different forms of food from seeds to fruit. The task requires children to define 3 categories of food, from the top to the bottom, the pictures depict rice, wheat, and potatoes.

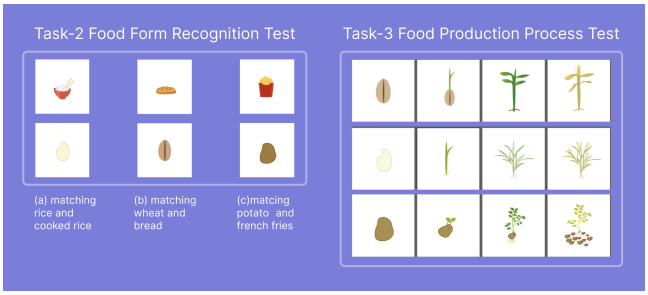

Figure 4: The left cards deck is used in task 2 for the food form recognition test. There are six cards, the three cards on the top depict the final food form: cooked rice, bread, and french fries. The three cards on the bottom are the initial food form: rice, wheat, and potato; The right cards deck are the materials we used in task 3, the Food Production Process Test.

A.3 Semi-structured Interview Script with Parents

Thank you for participating in this interview. We would like to briefly talk with you about your thoughts on children's play experience and knowledge related to the food production process. The interview is mainly divided into three parts, about 15-20 minutes, we will record and video the interview process, if you agree, we will continue.

A.3.1 Food Knowledge.

(1) Does your child know anything about food production and processing?
- And if so, where exactly did you learn it and show it?
- If not, do you think he or she can understand and learn the process of food production from this system?

(2) Can children learn from the system what the appearance of seeds of food is?
- If so, what kind of food and corresponding seed form can ta be learned, and where is it mainly reflected?
- If not, what exactly needs to be improved?

(3) Can he or she learn from the system what it takes to process food?
- Do you think there is any point in teaching children this knowledge?
- Would you like your child to learn more about this?

(4) Have you taught your children about privacy? What are you teaching them? How are they being taught?
- What tools do you use to teach, such as picture books, pictures, etc.
- How do you think the children's learning effect, how to teach them the most effectively?
- If you were designing content about food production and processing, what foods and steps would you most like to teach your children? and Why?

A.3.2 User Experience. **Overview**

(1) When playing systems, do you think your child is focused on the system?
- If so, where exactly is the reaction (expression, language, action, etc.) shown?
- If not, how can it be seen?

(2) By observing the children playing systems, do you think they can understand the changes in the food they are manipulating?

(3) Are there any images that are difficult for children to understand?

(4) Are there any prompts that aren't written enough, or that are difficult for the child to understand?

(5) Can these tools correspond to the tools and operations used in daily life?

Cube UI

(1) Do you think the interactions in this system, such as clicking buttons on a small square screen, are too difficult or too easy for your child?
- If so, at what point is this difficult? Why?
- If it's too easy, which step is too easy? Why?

(2) How much or how little help and direction do you find in this system?
- If not, where exactly do you need to add hints, and in what form?
- If so, where do you think the prompts should be reduced?

(3) What do you think of the feedback in this system? Do you give timely feedback to the children?
- If so, what specific actions did the feedback follow that were obvious or important to you?
- If not, where do you think more immediate feedback is needed?

Hands-on Props

(1) Do you have any ideas on the design and use of cardboard props?
- How do you feel about the actions and tools of sowing?
- How do you compare the watering action and the cardboard props to the ones you use in real life?
- What do you think of this operation of filtering that simulates the real situation?
- Does the combination of small cardboard props attract and encourage children to focus on continuing to play?

(2) Do you think this form can give children the motivation and pleasure of learning food knowledge?
- If so, can you tell me why?
- If not, why, and do you have any better suggestions?

(3) Do you think cardboard props can help children learn these things better?

Suggestion/ Recommendation

(1) How do you like this one compared to the kitchen, cooking, and planting toys or systems your child has played with before?

(2) Will knowledge learning have a better learning effect?

(3) What about playability and fun?
- If not, can you point out where you think our system is not good enough?

(4) How do you like this one compared to the toys or systems your child has played with gadgets like assembly?

(5) Do you think this form can give children the motivation and pleasure of learning food knowledge?
(6) Is it easier to get started?
(7) Is openness high enough?
(8) Is it more appealing to kids?
(9) Is there a better auxiliary effect for learning food-related knowledge?

A.3.3 Interview With Children. **Food Knowledge**

(1) Do you remember what kind of food was in the system we played?
(2) Do you normally eat these foods?
(3) What's your favorite food?
(4) Do you now know what steps these foods go through to become food?
(5) Can you tell me the one step you remember most clearly?
(6) Why do you remember this the most?

User Experience

(1) Do you like playing this system? How many out of 10 little stars would you give? (Print out the actual little star)
    - If yes, what is your favorite place?
    - If you don't like 0 minus 5, why not?
(2) After playing the system, do you understand what the system is about?
(3) How long did it take you to learn how to play?
(4) Is it easier than any other toy or system I've played?
(5) Do you remember what the cartoon pictures on the little square screen were?
    - Why do you remember this the best?
(6) Is there anything you can't read that's clear?
(7) Is it fun to manipulate small cardboard tools to accomplish tasks?
(8) What was your favorite play and why?
(9) What tools were used to accomplish this action?
(10) Can you understand how small cardboard tools can be used for seeding, watering, and sifting?
(11) Does the system play of the small cardboard tool remind you of any tools you use in life?
(12) Would you like to share the system you played today with your friends?
(13) In the future, if this system can be played with friends, and there are more ways to play such as farming and raising chickens, will you continue to play with your friends?
(14) Do you think you learned anything from playing this system?
(15) Do you know what seed bread is made from? (Ask one at random, according to the memory described by the child)